Additive manufacturing
(Rapid Prototyping)

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Additive manufacturing

The approved process categories according the standard ISO/ASTM 52900 are presented in the following list:

- material extrusion – an additive manufacturing process in which material is selectively dispensed through a nozzle or orifice
- material jetting – an additive manufacturing process in which droplets of build material are selectively deposited
- binder jetting – an additive manufacturing process in which a liquid bonding agent is selectively deposited to join powder material
- sheet lamination – an additive manufacturing process in which sheets of material are bonded to form a part
- vat photo-polymerization – an additive manufacturing process in which liquid photopolymer in a vat is selectively cured by light-activated polymerization
- powder bed fusion – an additive manufacturing process in which thermal energy selectively fuses regions of powder bed
- directed energy deposition – an additive manufacturing process in which focused thermal energy is used to fuse materials by melting as they are being deposited

Additive manufacturing – summary

Classification by initial material:

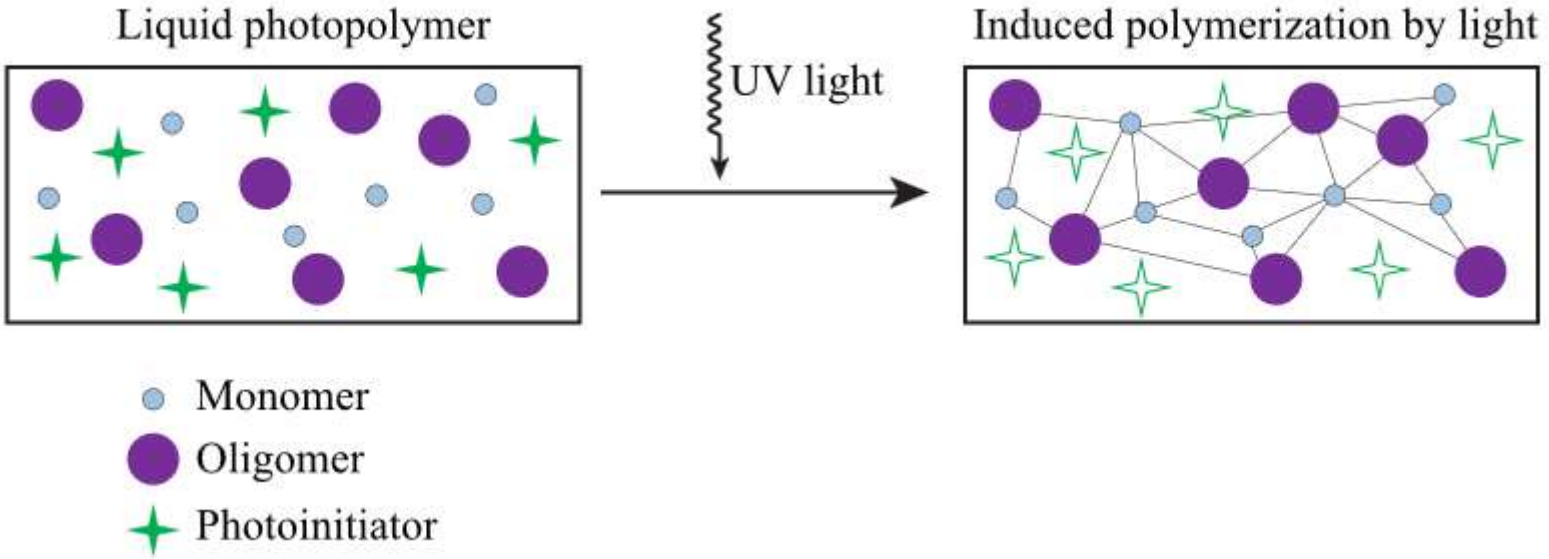
Liquid:
- Stereolithography Apparatus (SLA)
- Solid Ground Curing (SGC)
- Digital Light Processing (DLP)
- Polyjet printing

Powder:
- Selective Laser Sintering (SLS)
- Selective Laser Melting (SLM, DMLS)
- Three Dimensional Printing (3DP)
- Multi Jet Fusion (MJF)

Solid:
- Fused Deposition Modelling (FDM)
- Laminated Object Manufacturing (LOM)
- Thermoplastic Ink Jet (TIJ)
- ARBURG Plastic Freeforming (APF)

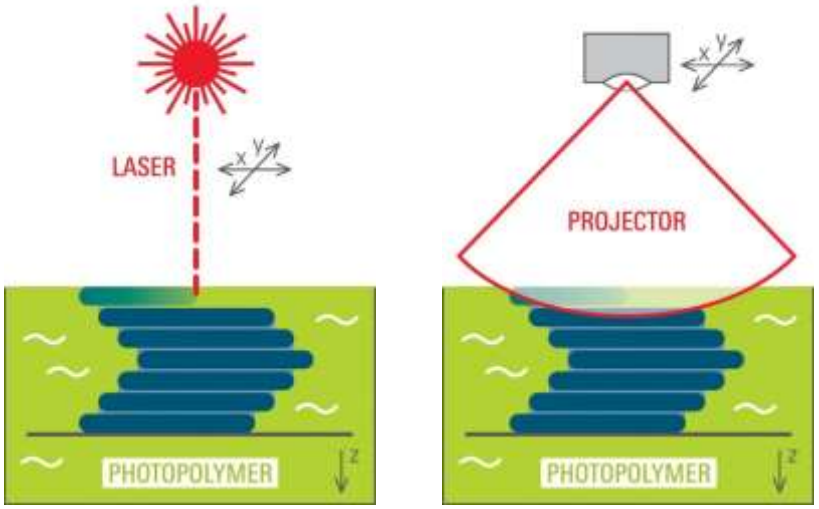
Photopolymer

- a polymer that changes its properties when exposed to light
- these changes are often manifested structurally, e. g. hardening of the material occurs as a result of cross-linking when exposed to light
- example is shown below depicting a mixture of monomers, oligomers, and photo initiators that conform into a hardened polymeric material through a process called curing.



Additive manufacturing

- vat photo-polymerization – an additive manufacturing process in which liquid photopolymer in a vat is selectively cured by light-activated polymerization



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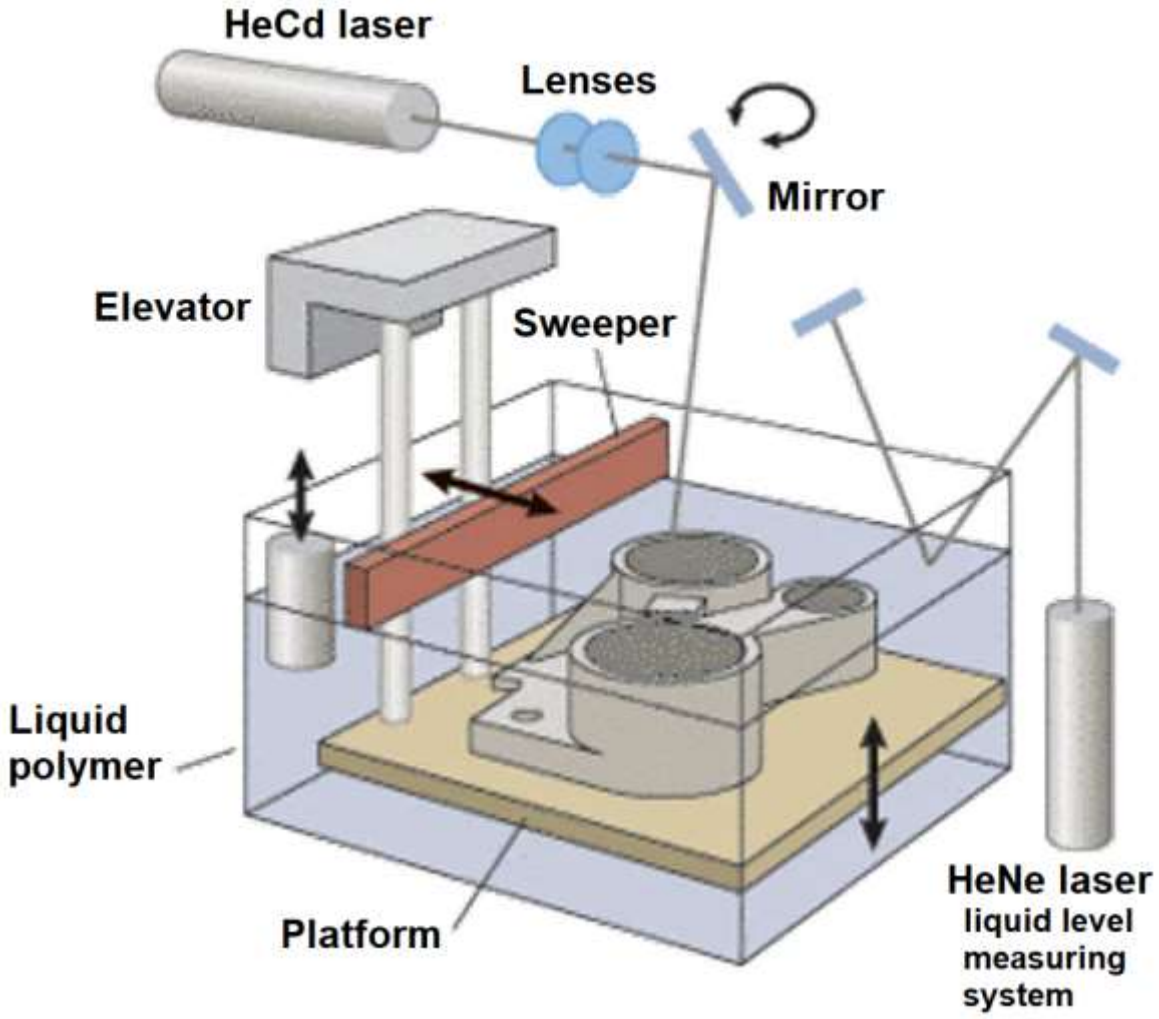
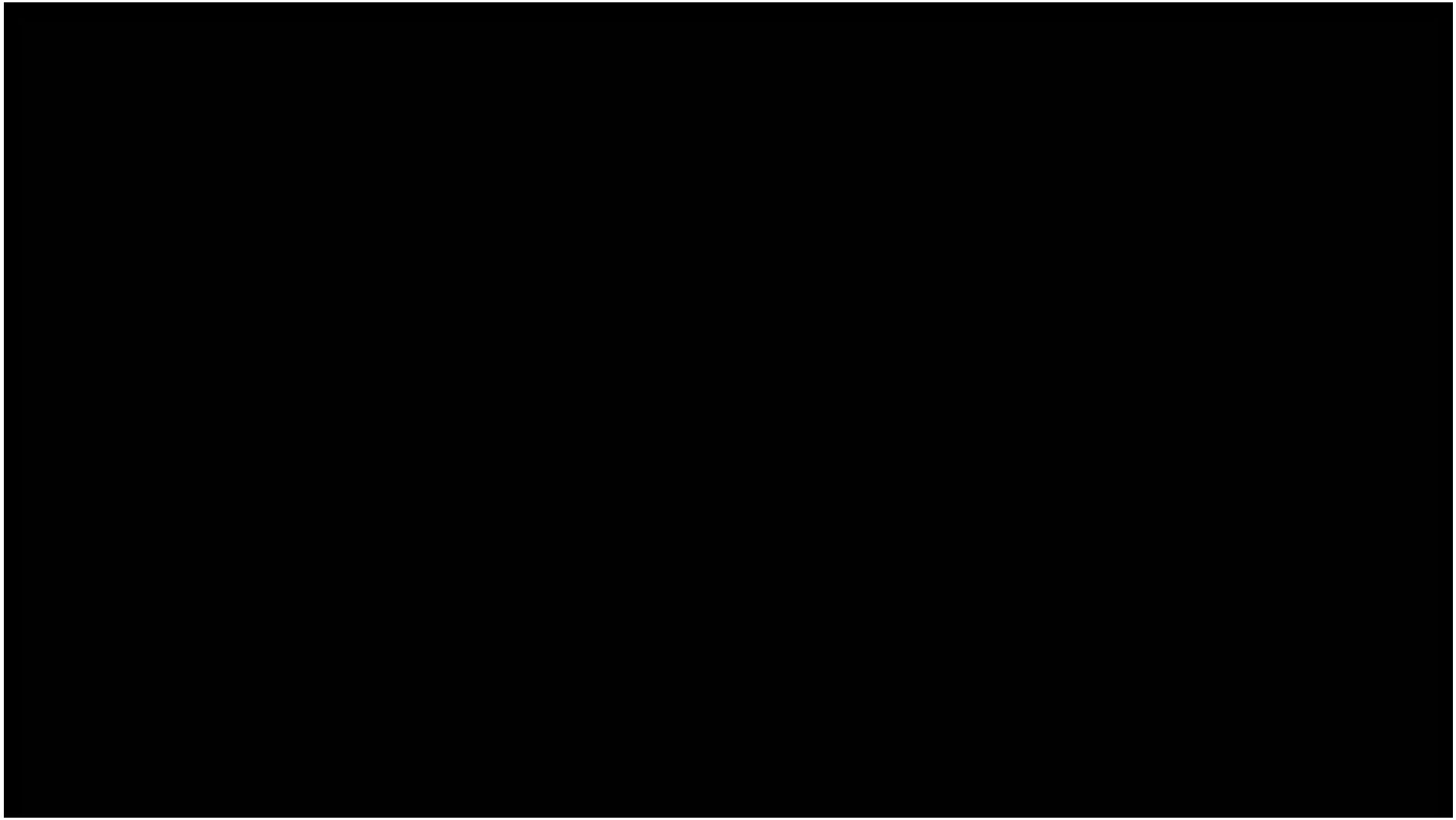
Stereolitography Apparatus

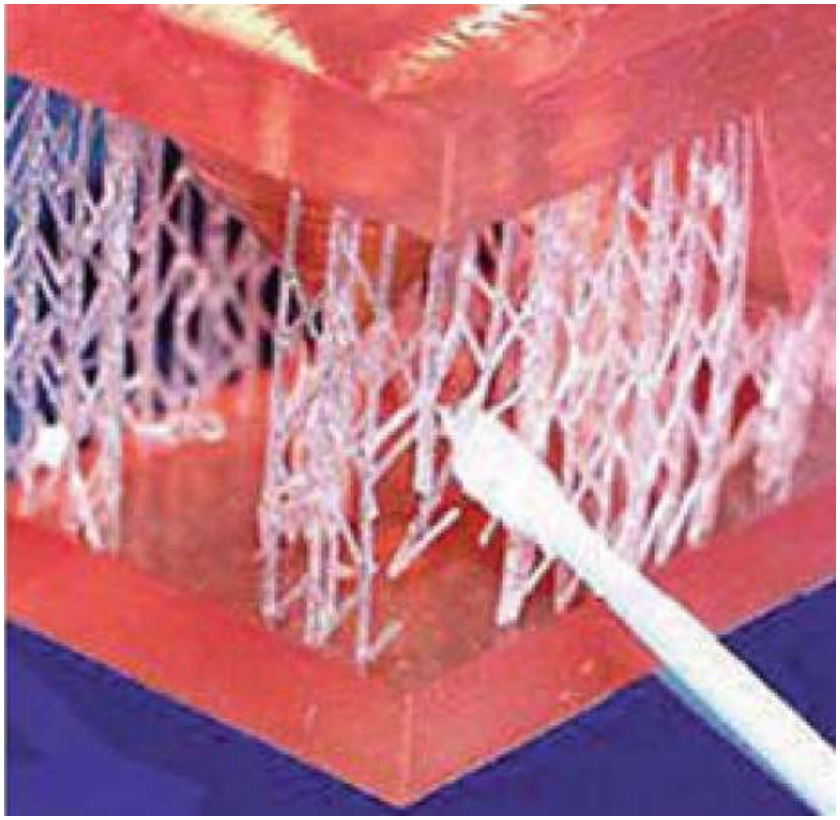


- curing the photopolymer selectively by laser in a thin layer on the surface
- liquid unprocessed photopolymer serves partly as a support, nevertheless it is necessary to build sparse supports for fixing the part on the platform
- the unprocessed photopolymer in the bath can be reused

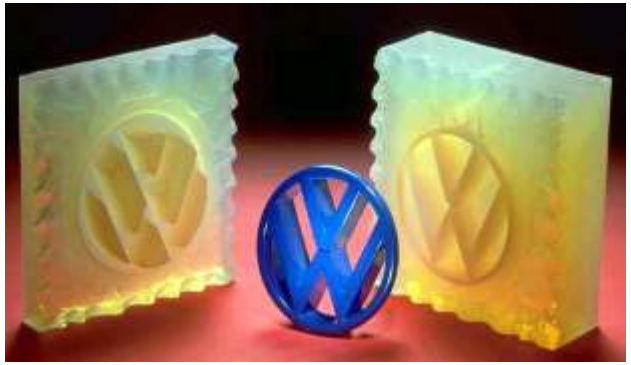
Stereolitography Apparatus



Stereolitography Apparatus

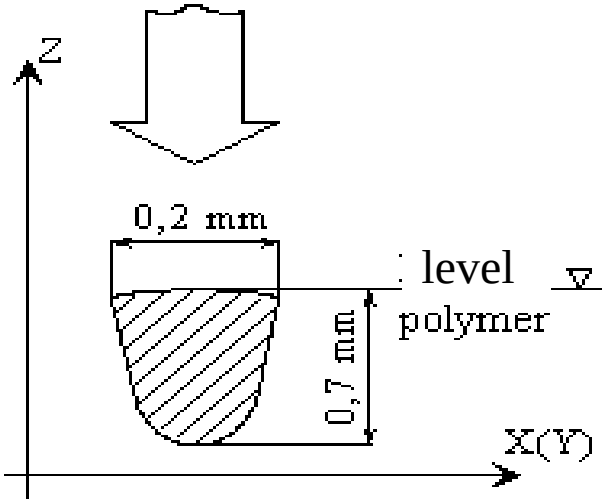


- the supports are made of the same material as the model itself (they are very thin, so they look clear)
- they are attached to the surface of the part with a very small area, they can be easily removed mechanically without leaving traces
- the part is "sticky" after removal from the bath, subsequent curing in UV light is required

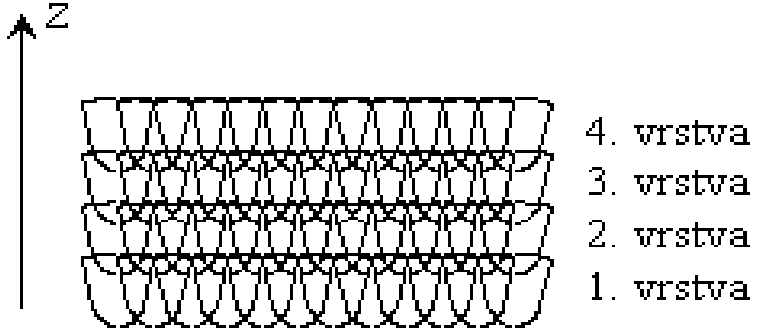


Principals of point to point layer ceration

Drop

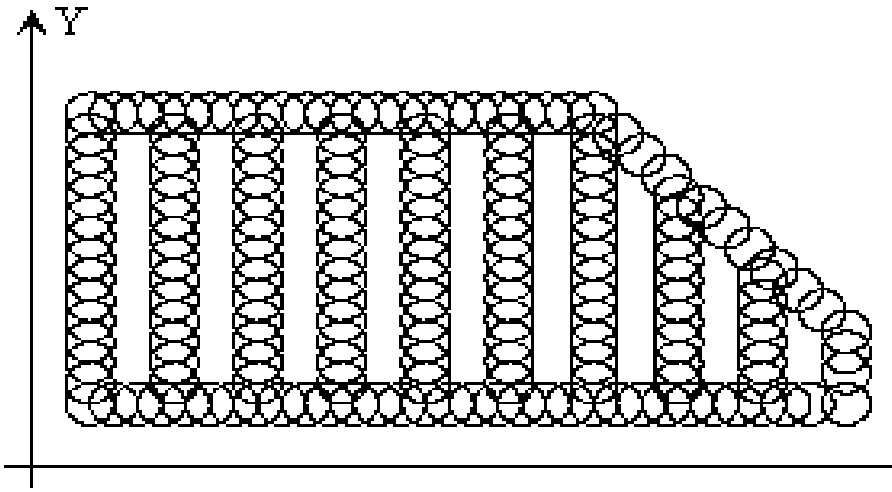


Building



Layer

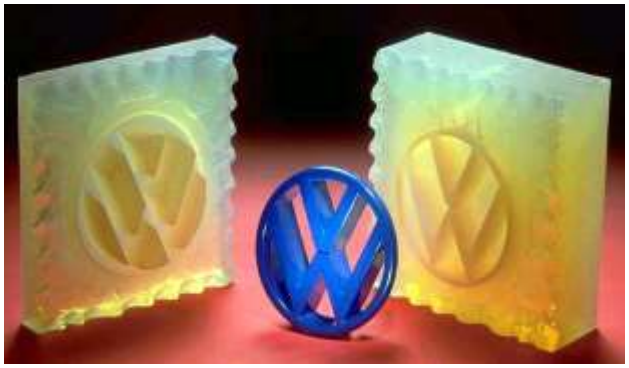
One layer mask



	Stereolithography (SLA)
Applications	Excellent for fit and form testing. Ideal for trade show-quality parts via painting and texturing. Best process for water resistant materials, not waterproof.
Maximum Dimensions	635 x 635 x 530 [mm]
Layer Thickness	High-Resolution: 0.050 - 0.100 [mm] Standard Resolution: 0.127 - 0.150 [mm]
Material Options	ABS-Like White (Standard & High Res), ABS-Like Gray, ABS-Like Black, Rigid PC-Like (Standard & High Res), Durable PP-Like (Standard & High Res), Semi-Flexible, High-Impact ABS-Like, High-Temp ABS-Like, High-Temp PC-Like, Rigid, & Technician's Choice
Recommended Minimum Feature Size	High-Resolution: 0.25 - 0.38 [mm] Standard Resolution: 0.64 - 0.89 [mm]

Advantages of SLA technology

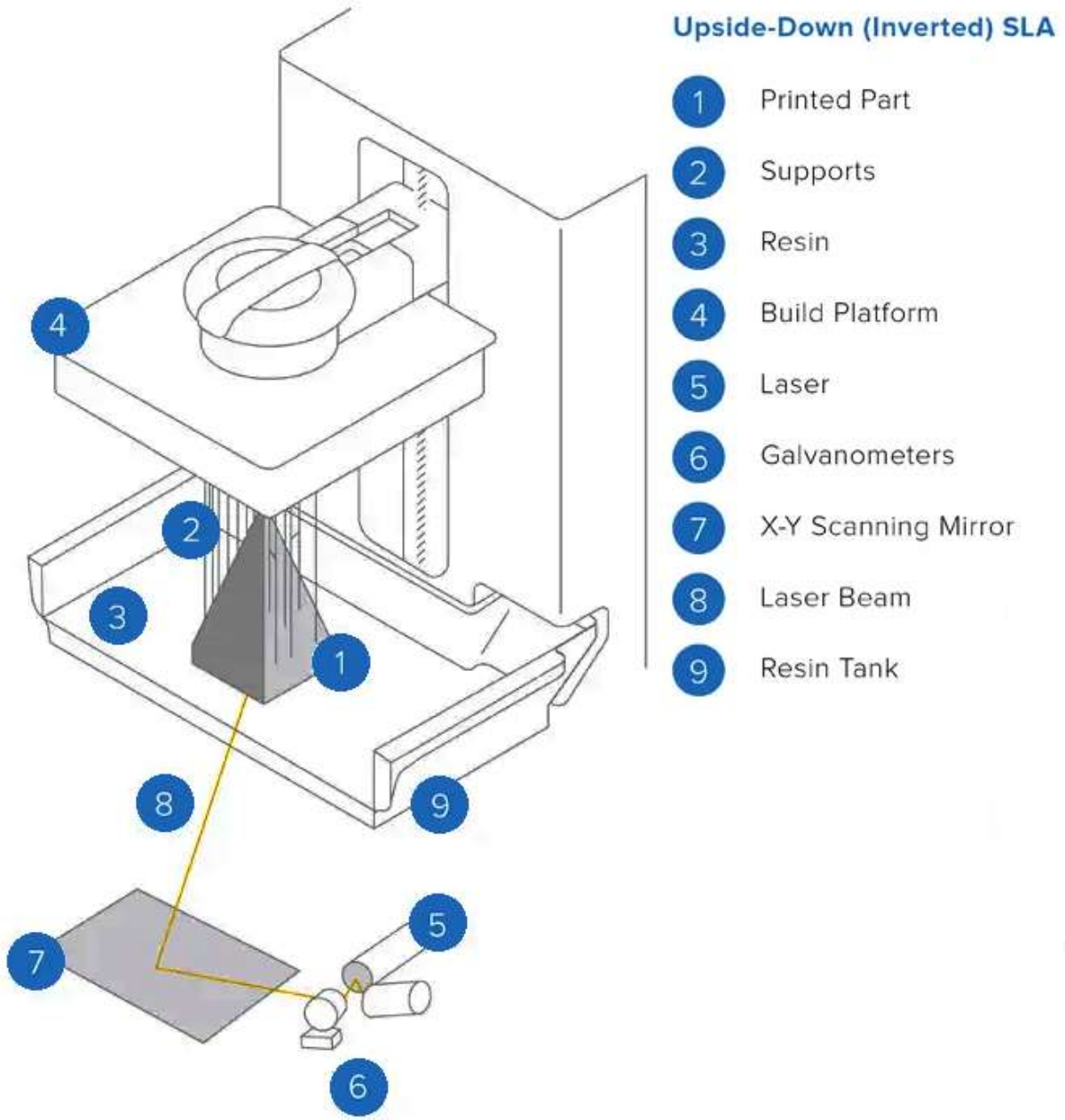
- fine surfaces
- a big volume
- high accuracy (+/- 0.05 mm)
- one of the best process for indirect tools manufacturing
- micro Stereolithography for very small parts (micro or millimetres) – still in development



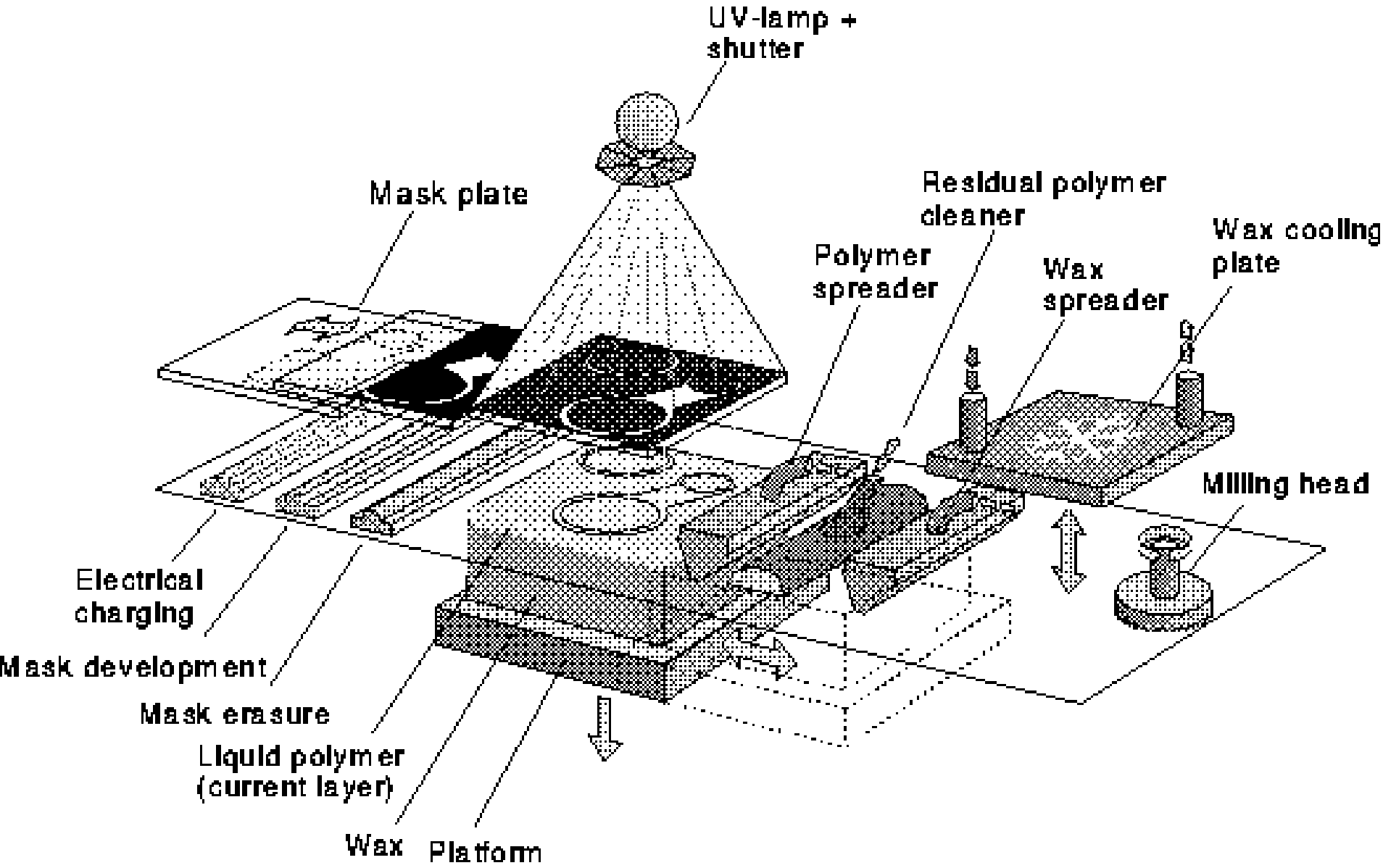
Disadvantages of SLA technology

- a high volume of expensive photopolymers
- fragile parts
- limited materials
- the liquid resin is very sensitive to humidity
- the liquid resins are a potential hazard
- post-processing is necessary

Inverted Stereolitography Apparatus



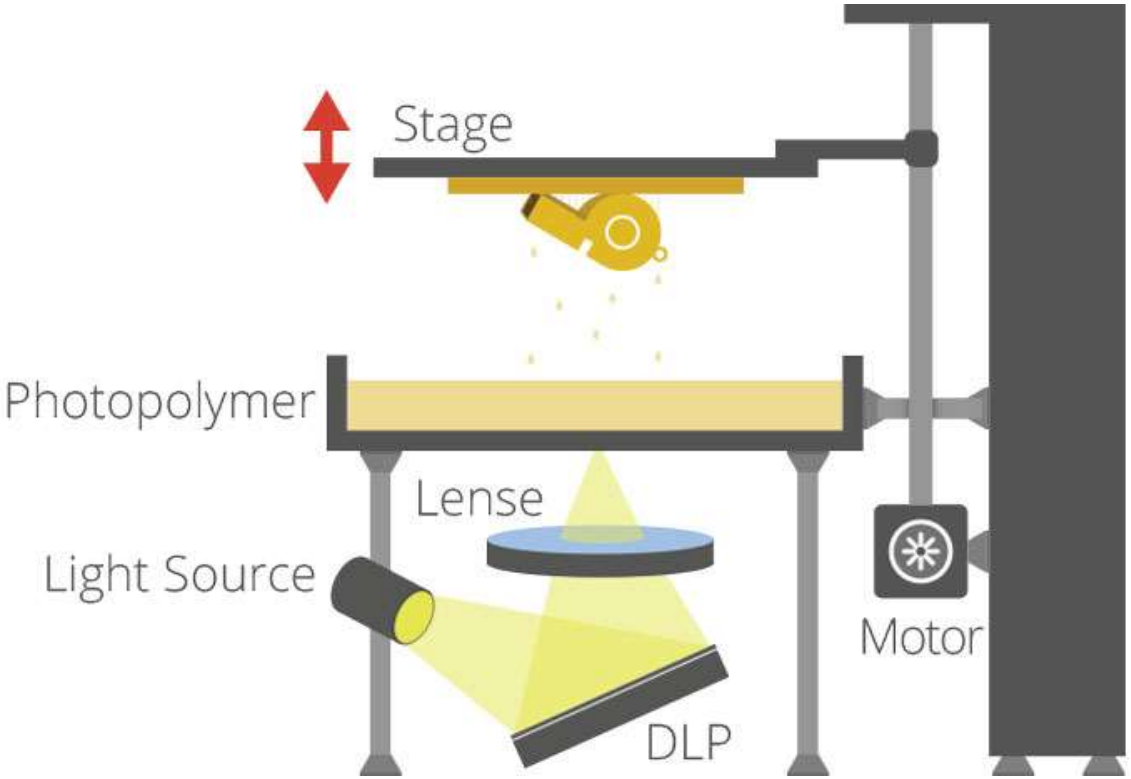
Solid Ground Curing

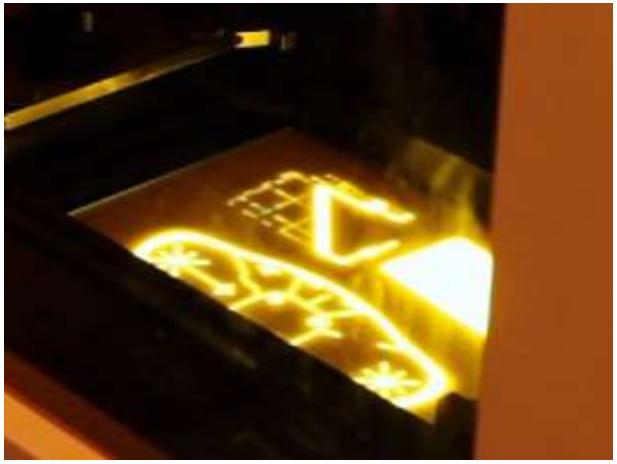


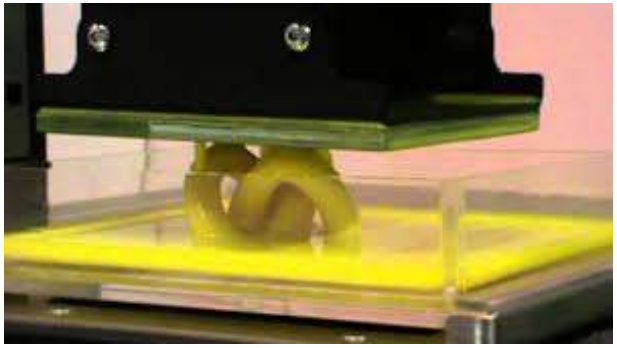
SGC: Solider

Machine	Solider SGC 4600	Solider SGC 5600
Volume [mm]	350 x 350 x 350	500 x 350 x 500
Accuracy [mm]	±0,084	±0,084
Planarity [mm]	0,15	0,15
Layer thickness [mm]	0,1 – 0,2	0,1 – 0,2
Speed	120 s / layer	65 s / layer
Price [USD]	about 200 000	about 350 000

Digital Light Processing







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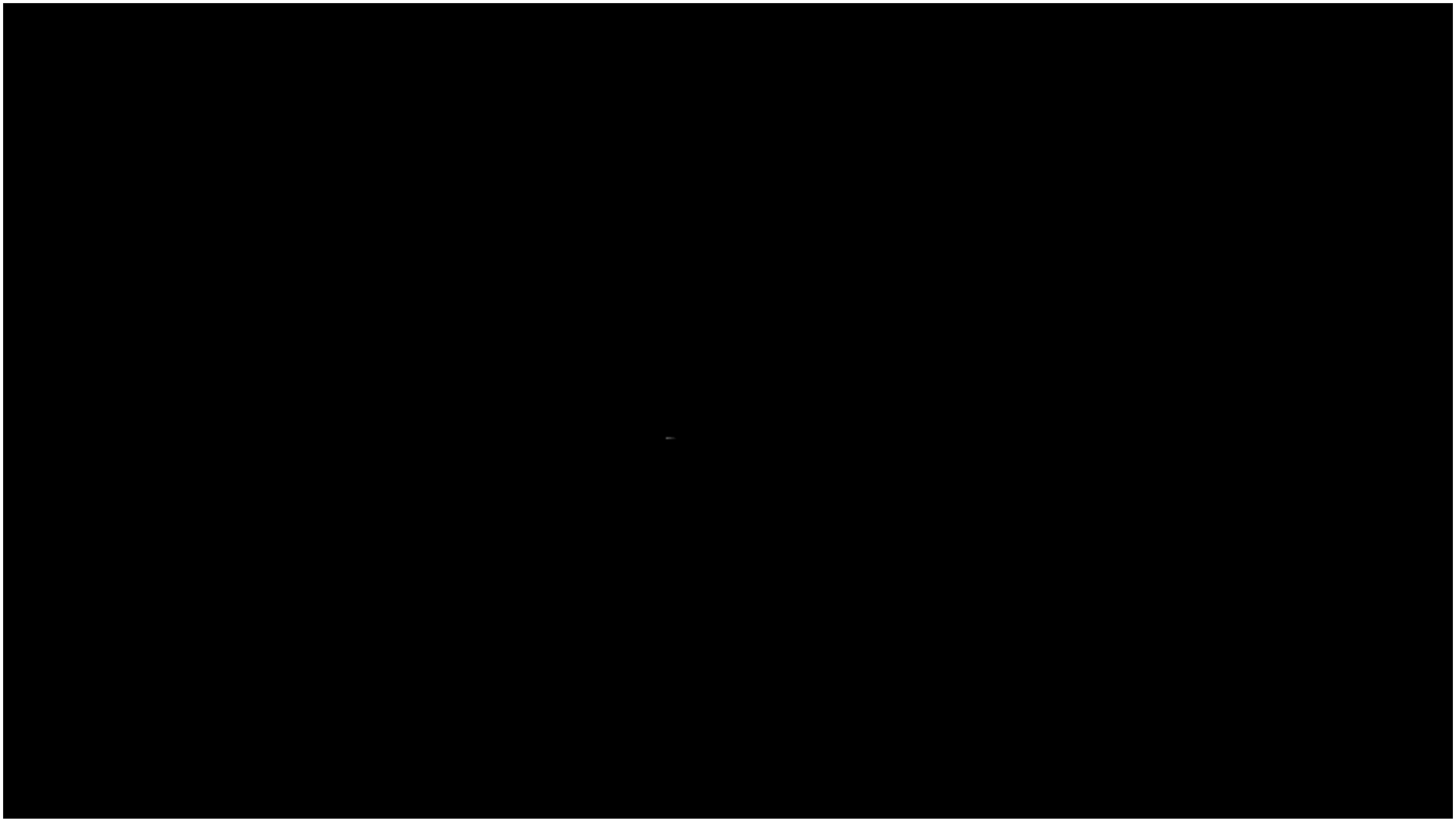

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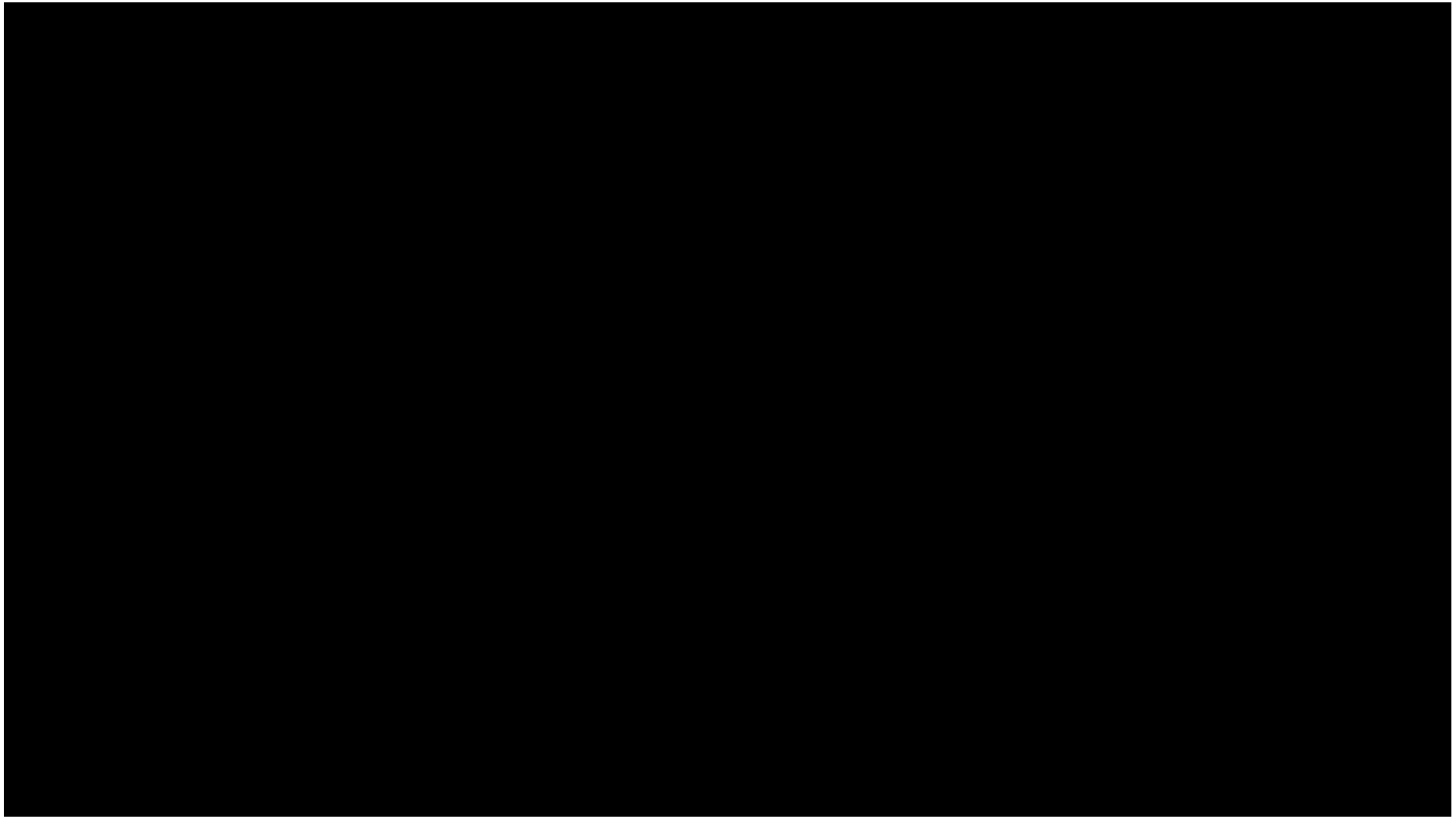


Advantages of Digital Light Processing

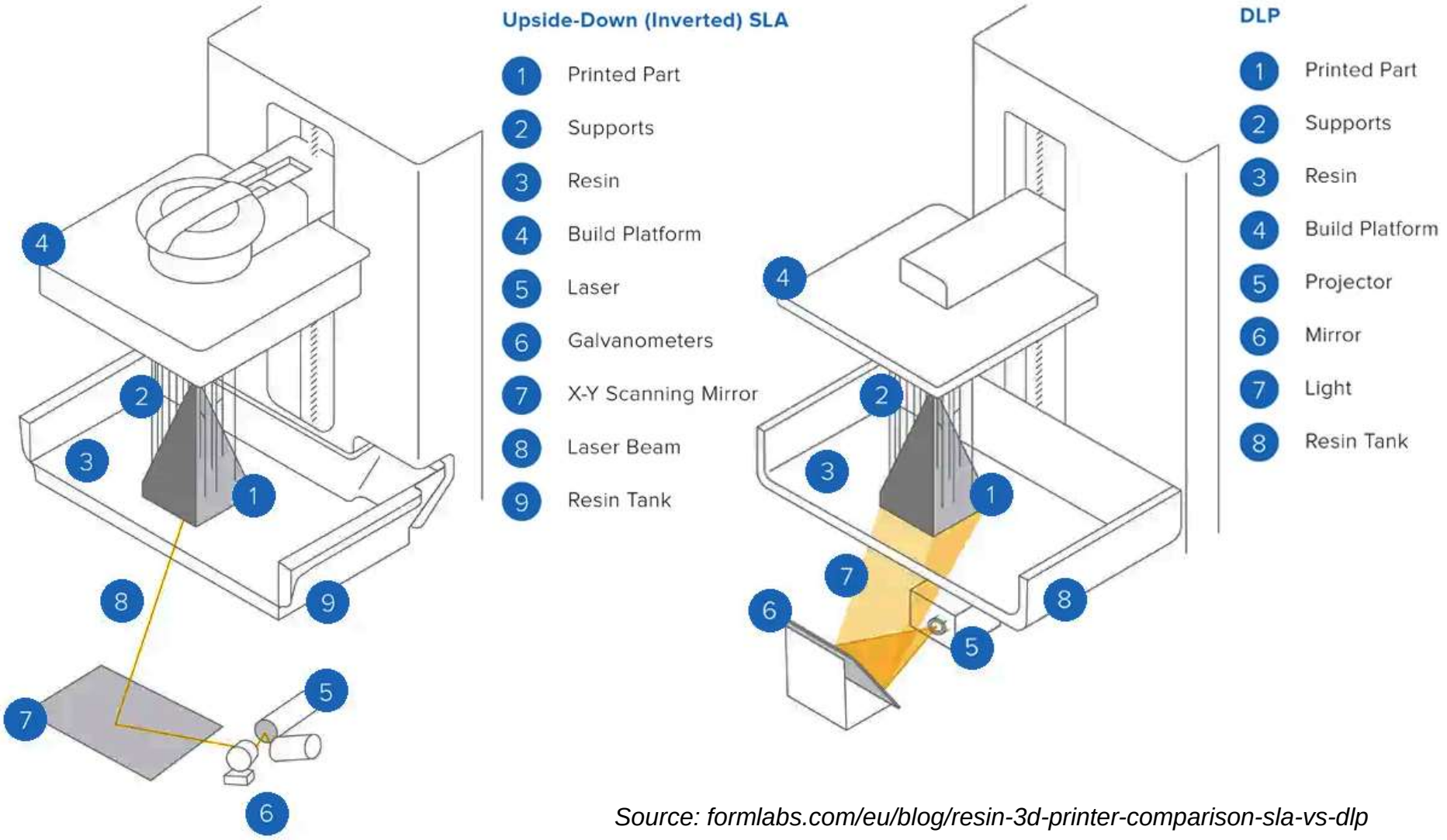
- **Relatively simple printing with good surface quality**
- Reverse principle - low consumption of photopolymer (it is enough if the level is higher than the thickness of the layer
- Also used for hobby printing
- Possibility of composite printing (eg photopolymer + ceramics)

Disadvantages of Digital Light Processing

- Materials based on photopolymers - usually have poorer mechanical properties, especially they are mostly fragile
- Relatively short service life of materials
- Worse dimensional accuracy against SLA

Vat photo-polymerization

SLA vs DLP



Source: formlabs.com/eu/blog/resin-3d-printer-comparison-sla-vs-dlp

Vat photo-polymerization

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Additive manufacturing

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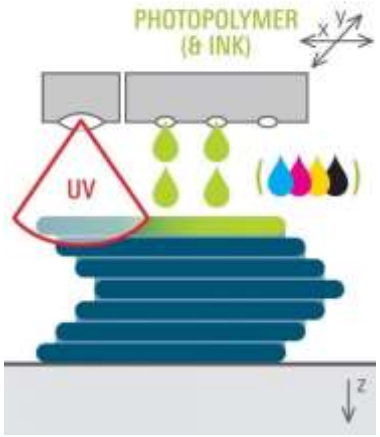

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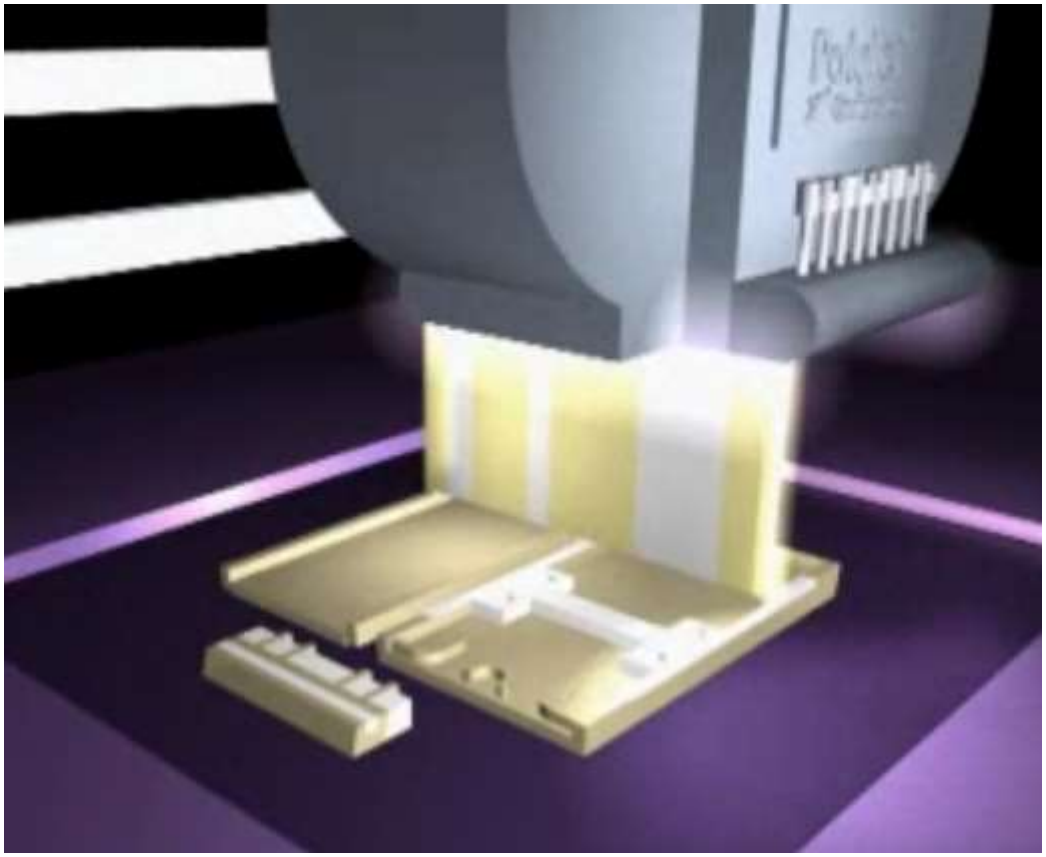
Polyjet Printing



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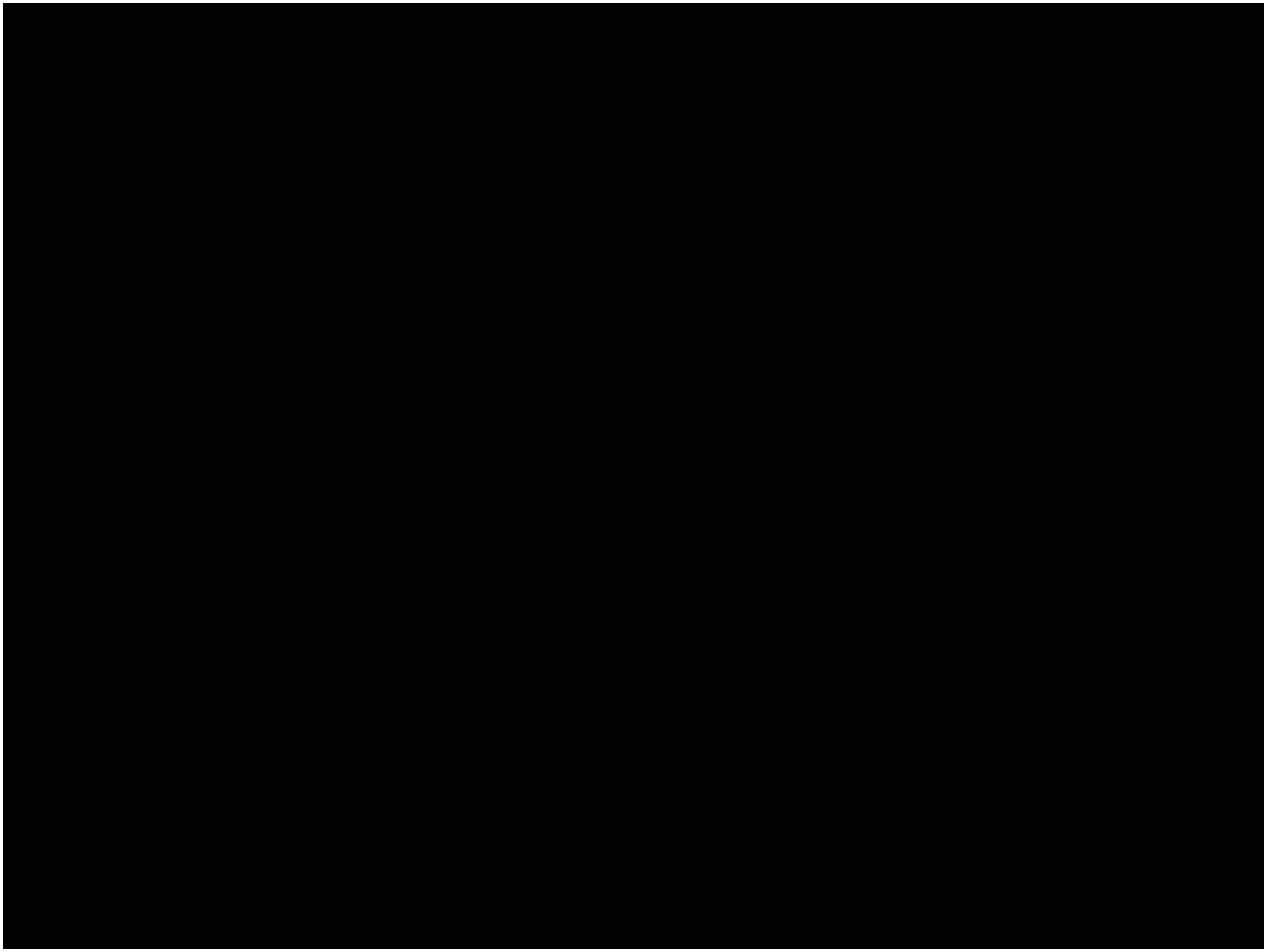

Stratasys J750

Stratasys J750

Product Specifications	
Model Materials	Vero™ family of opaque materials including neutral shades and vibrant colors Tango™ family of flexible materials Transparent VeroClear™ and RGD720
Digital Model Materials	Unlimited number of composite materials including: Over 360,000 colors Digital ABS and Digital ABS2™ in ivory and green Rubber-like materials in a variety of Shore A values Translucent color tints
Support Materials	SUP705 (WaterJet removable)
Build Size	490 x 390 x 200 mm (19.3 x 15.35 x 7.9 in.)
Layer Thickness	Horizontal build layers down to 14 microns (0.00055 in.)
Software	PolyJet Studio™ 3D printing software
Build Modes	High Speed: up to 3 base resins, 27-micron (0.001 in.) resolution High Quality: up to 6 base resins, 14-micron (0.00055 in.) resolution High Mix: up to 6 base resins, 27-micron (0.001 in.) resolution
Accuracy	20-85 microns for features below 50 mm; up to 200 microns for full model size (for rigid materials only)
Resolution	X-axis: 600 dpi; Y-axis: 600 dpi; Z-axis: 1800 dpi

Advantages of PolyJet Printing

- **Possibility to combine materials**
- Full colour printing
- Layer thickness 14 μm - excellent surface quality
- Materials can be combined with each other - so called digital materials - modification of properties

Disadvantages of PolyJet Printing

- Materials based on photopolymers - usually have poorer mechanical properties, especially they are mostly fragile
- Relatively short service life of materials
- Immediately after printing, the printer heads need to be cleaned or they will dry out